

PEROXISOME

Structure, Biogenesis, Enzyme Content and Functions — Study Notes

1. Introduction

Peroxisomes are small, single-membrane-bound, oxygen-utilising cytoplasmic organelles found in almost all eukaryotic cells (except mature mammalian RBCs). They were first isolated and characterised by **Christian de Duve** (1965–67), who also named them for their role in hydrogen peroxide metabolism. Unlike mitochondria and chloroplasts, peroxisomes contain no DNA or ribosomes of their own and are not part of the endomembrane (ER–Golgi) secretory pathway in the classical sense, although the ER contributes membrane and some proteins during their biogenesis.

2. Occurrence, Size and Distribution

- Present in virtually all eukaryotic cells — abundant in **liver and kidney** cells (up to several hundred/cell), and as **glyoxysomes** in germinating fatty seeds and **leaf peroxisomes** in green tissue of plants.
- Spherical to ovoid, **0.2–1.0 μm** in diameter (average $\sim 0.5 \mu\text{m}$).
- Bound by a **single unit membrane** ($\sim 7\text{--}8 \text{ nm}$), enclosing a granular **matrix**; some peroxisomes (liver, kidney) show a dense **crystalloid core / nucleoid** made largely of the enzyme urate oxidase.
- **Self-replicating**: multiply mainly by fission of pre-existing peroxisomes (also by budding from the ER), analogous to mitochondria and chloroplasts, but without their own genome.

3. Structure and Functions — Schematic Diagram

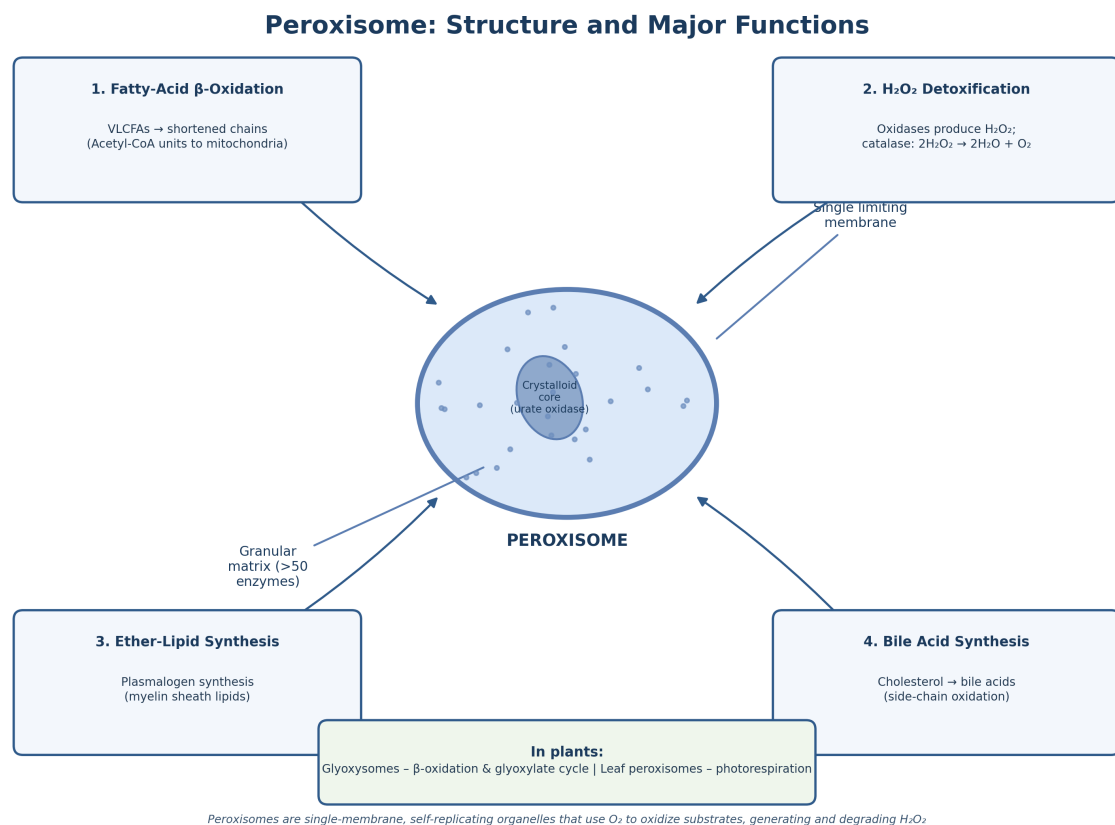


Fig. 1: Peroxisome structure (membrane, matrix, crystalloid core) with its four principal biochemical functions.

4. Biogenesis

Peroxisomal matrix proteins are synthesised on **free cytosolic ribosomes** (not on rough ER) and are post-translationally imported into pre-existing peroxisomes. Import is directed by short C-terminal or N-terminal targeting sequences — **PTS1** (peroxisomal targeting signal-1, a C-terminal -SKL tripeptide) and **PTS2** — which are recognised by cytosolic receptor proteins called **peroxins** (PEX5 for PTS1, PEX7 for PTS2), encoded by **PEX genes** (~14 known in humans). New peroxisomes also arise by growth and fission of existing ones, and pre-peroxisomal vesicles can bud from the ER.

5. Enzyme Content

The peroxisomal matrix contains more than 50 different enzymes. Two broad functional classes dominate:

Class	Examples	Role
Oxidases	Urate oxidase, D-amino acid oxidase, Acyl-CoA oxidase, Glycolate oxidase	Transfer H from substrate to O_2 , producing H_2O_2
Catalase	Catalase (up to ~40% of matrix protein)	Breaks down $H_2O_2 \rightarrow H_2O + O_2$; also peroxidatic oxidation of toxins
β -oxidation enzymes	Acyl-CoA oxidase, enoyl-CoA hydratase, 3-hydroxyacyl-CoA dehydrogenase, thiolase	Chain-shortening of very-long-chain fatty acids (VLCFAs)
Biosynthetic enzymes	DHAP acyltransferase, alkyl-DHAP synthase	Plasmalogen (ether phospholipid) synthesis

6. Functions of Peroxisomes

6.1 β -Oxidation of Fatty Acids

Peroxisomes chain-shorten **very-long-chain fatty acids (VLCFAs, >C22)** and branched-chain fatty acids by β -oxidation, producing acetyl-CoA and a shorter fatty acid. Unlike mitochondrial β -oxidation, the first oxidation step uses **acyl-CoA oxidase**, which transfers electrons directly to O_2 , generating H_2O_2 (no direct ATP yield at this step). The shortened products are exported to mitochondria for complete oxidation.

6.2 Hydrogen Peroxide Metabolism (Detoxification)

Various oxidases generate H_2O_2 while oxidising substrates such as amino acids, uric acid and fatty acids. **Catalase** then either converts H_2O_2 to water and oxygen ($2H_2O_2 \rightarrow 2H_2O + O_2$) or uses it to oxidise toxic substrates such as **phenols, formaldehyde and ethanol** (peroxidatic reaction) — an important route of alcohol detoxification in liver and kidney cells.

6.3 Lipid Biosynthesis

Peroxisomes carry out the first steps of **plasmalogen** synthesis — ether phospholipids that are major components of the **myelin sheath** of nerve cells and of cardiac muscle membranes. They also participate in **cholesterol** and **dolichol** synthesis, and in the side-chain oxidation of cholesterol to form **bile acids** in the liver.

6.4 Purine and Amino Acid Catabolism

The crystalloid core of liver/kidney peroxisomes is rich in **urate oxidase**, which oxidises uric acid during purine breakdown (note: humans lack functional urate oxidase, so uric acid is the excretory end product). **D-amino acid oxidase** and **L-amino acid oxidase** catabolise unusual amino acids.

6.5 Photorespiration and Glyoxylate Cycle (Plants)

In green leaves, **leaf peroxisomes** (with chloroplasts and mitochondria) carry out the **glycolate pathway of photorespiration**. In germinating oil-rich seeds, specialised peroxisomes called **glyoxysomes** house the **glyoxylate cycle**, converting stored fats into sugars for the growing seedling.

7. Clinical Correlation: Peroxisomal Disorders

Defects in peroxin (PEX) genes impair peroxisome assembly/import and cause a spectrum of inherited metabolic diseases, generally marked by VLCFA accumulation:

- **Zellweger syndrome** (cerebro-hepato-renal syndrome) — severe, due to failure of peroxisome biogenesis; near-total loss of peroxisomal function.
- **X-linked Adrenoleukodystrophy (X-ALD)** — defective VLCFA β -oxidation due to a peroxisomal membrane transporter (ABCD1) defect; progressive demyelination.
- **Refsum disease** — defective α -oxidation, leading to phytanic acid accumulation.

8. Peroxisome vs Lysosome vs Mitochondrion (Quick Comparison)

Feature	Peroxisome	Lysosome	Mitochondrion
Membrane	Single	Single	Double
Own DNA/ribosomes	No	No	Yes
Key enzymes	Oxidases, catalase	Acid hydrolases	Respiratory chain enzymes
Main role	Fatty-acid oxidation, H_2O_2 metabolism	Intracellular digestion	ATP generation (oxidative phosphorylation)
pH of interior	~Neutral	Acidic (~5)	~Neutral/alkaline matrix

Quick Revision: Single membrane · no DNA · discovered by de Duve · self-replicating · catalase + oxidases · β -oxidation of VLCFAs · plasmalogen & bile-acid synthesis · glyoxysomes (glyoxylate cycle) and leaf peroxisomes (photorespiration) in plants · PEX genes/peroxins → PTS1/PTS2 import · Zellweger syndrome & X-ALD are key disorders.